The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

1. Introduction

In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality, and is ready to respond, if necessary. *[Images may include standard radiation images – the symbols (old and new), some images of the disaster – smoldering fire, helicopters, first responders, people spraying water to decontaminate …]*

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. and in such an event, this discussion will examine an event that forced the USSR to confront some of the same issues: response and recovery from the Chernobyl nuclear incident. The Chernobyl incident was the uncontrolled meltdown of one of the core reactors of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine. The meltdown caused a fire that burned for 10 days, emitting enormous amounts of radiation into the atmosphere, and contaminating large parts of Ukraine, Belarus, Russia, and western Europe. In this documentary, we'll examine how recovery from that that incident was managed, focusing on effective countermeasures in the aftermath of the disaster and eventual restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. *[More detailed resumes when they first appear on screen]*

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with U.S. EPA, explains why this documentary focuses on Chernobyl:

> *[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]*

Before we delve into the details of the Chernobyl incident, we need to refresh our knowledge of some key concepts about radioactivity. For the next few minutes, we'll define what radioactivity is, different types of radioactivity, and the key differences between the types and persistence of radioactivity released by nuclear power plant disasters, nuclear bombs, and radioactive dispersal devices, or "dirty bombs".

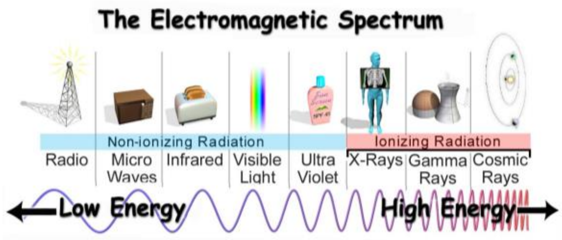
Outline of what's to come *(1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.*

2. General Info about Radioactivity and nuclear devices

2.1 A Radiation Primer

To understand some of the concepts we will present in this documentary, it is important to first review some basic radiation terminology and characteristics.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms. These types of radiation do not have enough energy to cause damage to living tissue, and are called *non-ionizing radiation*.



The other general category of radiation is called *ionizing radiation* which does have enough energy to cause damage to living tissue. Ionization is a destructive process that causes atoms or molecules to lose electrons. X-rays, cosmic rays, and nuclear radiation are types of ionizing radiation.

Many radioactive materials occur naturally. For example, granite contains remnant radioactive isotopes from the formation of the earth, and when granite erodes, these radioisotopes are carried away as sand and clay that form the soil around us – there are beaches in Brazil with such high natural radiation levels that they have restricted access. Sand and clay are also used to make building materials such as brick and concrete, which may emit low levels of radiation. Other naturally occurring radioactive isotopes are created when cosmic rays interact with atoms in the atmosphere. We are also exposed to manmade radioactive materials that have been released into the environment. Nuclear weapon testing has contributed to a slight increase in background radiation. You may also be exposed to radiation through medical procedures such as x-rays. You are exposed to radiation, known as background radiation, every day, and the amount of background radiation you are exposed to depends on where you live.

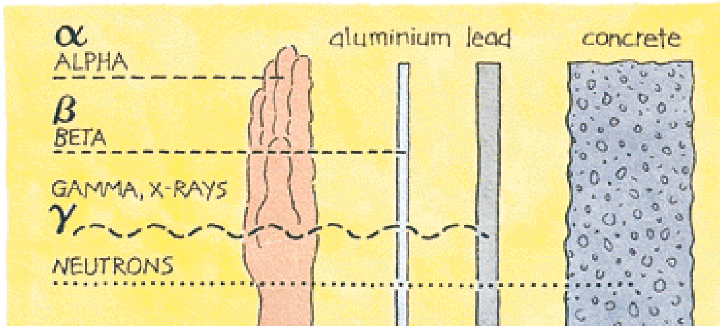
Nuclear radiation, which comes from the nucleus of an atom, is the type of radiation that most people think of when discussing radioactivity, and that is the focus of our discussion.

Remember that an atom is made of neutrons and protons that form the nucleus and electrons that orbit around the nucleus. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* There are over100 different types of atoms and each has a specific number of protons that identifies the atom as an *element*, such as oxygen or iron. For example, the element uranium always has 92 protons. However, the number of neutrons can vary. Elements with the same number of protons but different numbers of neutrons are called *isotopes*. For example, uranium can have 138 neutrons or 146 neutrons. Uranium with 146 neutrons is known as the isotope U-238.

[Graphic: table of uranium isotopes]

Radionuclide	**Protons**	**Neutrons**
Uranium-230	92	138
Uranium-235	92	143
Uranium-238	92	146

Certain isotopes are unstable because they have too many protons or neutrons. They essentially have too much energy and they release that extra energy to become more stable. This happens spontaneously and is called *radioactive decay,* and these isotopes are radioactive and are called *radioisotopes*. Radioisotopes release energy primarily as four types of radiation: alpha particles, beta particles, gamma rays, and neutrons. Each type of radiation has a different ability to penetrate materials *[see graphic]*. For example, alpha particles can be stopped by a piece of paper, whereas gamma rays can penetrate skin and thin sheets of metal.



Nuclear radiation is measured in several different ways. When we talk about the amount of radioactive material, we don't use weigh or volume because it does not have much meaning. Instead, we talk about the amount of radiation emitted from the material, the *radioactivity* (or *activity* for short) of the material.

Activity is usually measured in *curies,* which is the amount of radiation emitted by one gram of Radium-226. A curie is equal to 37 billion disintegrations per second, or 37 billion gamma rays, alpha particles, or beta particles per second. The physical amount of material to make one curie could be one gram of Radium-226 or thousands of kilograms of some other radioactive material. That is why the amount of material is not important but the activity of the material is!

The activity of a radioactive material is closely related to the material's *half-life,* or the amount of time it takes for the radioactivity of the material to decrease by half. For example, if the half-life of a radioisotope is one day, then after one day, half of the material will have decayed. The remaining half is still radioactive, so after another day, half of this portion will have decayed. The decay process continues until no more radioactive material remains. Depending on the starting amount, it takes about 7 to 10 half-lives before the radioactivity is near background levels of radiation.

Each radioactive isotope has a unique half-life. *[graphic - half-life table]* Half-lives of some isotopes are billions of years; other isotopes have half-lives of just a few seconds. Isotopes with shorter half-lives have higher activity, and tend to pose more serious health threats. This makes sense because a short half-life means a material is emitting a lot of radiation in a short time.

Isotope	**Half-Life**	**Origin**	**Uses**
Uranium-238	4.5 billion years	Naturally occurring	Armor-piercing projectiles
Carbon-14	5,730 years	Naturally occurring	Carbon dating fossils
Cesium-137	30 years	Manmade	Geiger counters
Iodine-131	8 days	Manmade	Treat thyroid cancer
Technetium-99m	6 hours	Manmade	Medical imaging
Strontium-97	9 seconds	Manmade	None

Half-life is also important from the perspective of environmental cleanup. If a material with a long half-life is released, it will take a long time to decay to a harmless level. Cesium-137, one of the isotopes released by the Chernobyl accident, has a half-life of 30 years. Cesium-137 continues to be the primary contaminant of concern in most of the areas affected by the Chernobyl accident to this day. After 32 years, almost half of the Cesium-137 released by the accident remains. On the other hand, one of the other major isotopes released by the accident (Iodine-131) has a half-life of 8 days. Iodine-131 was a major health concern shortly after the accident, but it has decayed away by now and it is no longer a problem.

There is one more basic element of radioactivity that we'll need to understand before we proceed: *nuclear reactions*. A nuclear reaction is one where the nucleus of an atom is changed, releasing incredible amounts of energy. At Hiroshima and Nagasaki, *uncontrolled* nuclear reactions occurred in a split second, releasing huge amounts of energy and radioisotopes with short half-lives. Most of these short half-life isotopes have decayed away, and the cities of Hiroshima and Nagasaki are now vibrant urban centers. C*ontrolled* nuclear reactions such as those used at nuclear power plants, on the other hand, take place over longer periods and create more radioisotopes with long half-lives. Both controlled and uncontrolled nuclear reactions create long and short half-life radioactive isotopes, but a controlled nuclear reaction creates a much higher proportion of long half-life isotopes. This is a fundamental reason that Hiroshima and Nagasaki are active urban centers with large populations, but the exclusion zone around the Chernobyl plant is expected to be uninhabitable for hundreds of years.

[NOTE – We may need to get into the discussion of dose later in the documentary, especially when we kick into the residual levels of contamination that are left. At this point, we've defined too many new terms, yet hit the highlights – isotopes are created by nuclear reactions, and they can be radioactive. The short half-life isotopes are a problem because they release a lot of energy fast. The longer half-lives are an ongoing problem because they really don't go away.

In a similar vein, we may want to introduce the idea of fallout, dispersal patterns, and hot particles later rather than here in the primer. I chose to put that later in the story, as this is a long section with a lot of new terms and it's pretty dry – best to keep it short and focused if we can.]

2.2 Types of incidents we might face - *Introduce the types of incidents we might face and draw distinctions between them:*

Now that we've covered some of the basics of nuclear radiation, we need to consider what sort of threats we are up against. Terrorists are unlikely to engage in conventional warfare. Quite simply, they're outnumbered and outgunned. To compensate for this handicap, they seize whatever advantage they can to even the odds and multiply their influence. One worrisome possibility is that terrorists may gain access to chemical, biological, or radiological agents. This documentary focuses only on radiological agents. There are three ways terrorists might release radioisotopes: radiological dispersal devices (RDDs) that release radioactive materials without creating a nuclear reaction, causing a release from a nuclear power plant, or an improvised nuclear bombs.

<u>Radioactive dispersal device (RDD):</u>

- An RDD is a device that disperses radioactive materials. It could be a conventional bomb that contains radioactive materials and scatters those materials and other debris when it detonates, or it could scatter radioactive materials using a non-explosive device, such as a crop duster. The easiest and therefore most likely way to release radiological agents would be to detonate a type of RDD known as a dirty bomb. *[image – an explosion in a city]* This type of weapon would use radioactive materials, but the materials would not undergo a nuclear reaction that releases large quantities of energy or creates radioisotopes. An RDD would probably use existing medical radioactive materials such as Cesium-137 and Cobalt-60 which are used to treat cancer or industrial radioactive materials such as Americium-241 and Iridium-192, which are used in devices that measure density and thickness.
- A dirty bomb could cause serious injuries from the explosion, but it most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. *[Dirty bomb clip from REMM Website radiation principals video? http://remm.nlm.nih.gov/radprinciplesvideo.htm]*
- An RDD would likely involve contamination over a densely populated area and initial confusion and lack of information, but would differ from Chernobyl in that the contaminated area would be

significantly smaller and the total amount and intensity of radioactivity released would likely be much, much lower.

A second way terrorists could release radioactive materials would be to intentionally cause an accident at a <u>Nuclear Power Plant (NPP)</u>.

- Radioactive materials could be released from a nuclear plant by a fire or explosion or an accident involving the reactor core.
- The world has suffered several NPP accidents, including the Chernobyl meltdown in 1986, partial meltdowns at the Three Mile Island nuclear plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952, and radioactive releases caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a nuclear plant near Kashiwazaki , Japan in 2007. *[still images of a couple of these disasters – TMI and images of steam being released from the Kashiwazaki plant ought to be available – perhaps response personnel running around as well.] From Google images "Kashiwazaki":*



- There are a several technical reasons that a nuclear accident like the Chernobyl meltdown are not likely to happen in America. First, the design of all U.S. reactors is different from the design of the Chernobyl reactor, and second, safety and design regulations are more stringent. The technical design of U.S. reactors is different than the Chernobyl reactor and makes major releases of radioactive materials extremely unlikely, if at all possible.

The most devastating way to release radiological agents would be to construct and detonate an <u>Improvised Nuclear Device (IND)</u>.

- An IND is a small nuclear bomb where materials undergo a nuclear reaction. An IND would be catastrophic and would likely cause mass casualties. The technical difficulty of obtaining the materials and creating the conditions for a nuclear reaction make this a less likely scenario than an RDD. . However, a stolen nuclear weapon by a terrorist organization is of great concern. *[graphic – mushroom cloud]*
- The contaminated area would be big but the amount of highly contaminated land would still be smaller than Chernobyl. The reasons for this are complex, but simply put, a nuclear bomb produces less radioactive materials and spreads them less far than the Chernobyl accident.
- Most of the types of radioactive materials released by an IND would decay relatively quickly; most is gone within the first 24 hours and almost all within 2 weeks. However, a small amount of residual contamination would remain for a relatively long time.

<u>Summary:</u> To sum up, we face three main types of incidents that might release radioactive materials: RDDs, nuclear power plant accidents, and improvised nuclear bombs.

- A dirty bomb is probably the most likely scenario, and it would likely disperse commercially available medical or industrial radioactive materials over a wide area without undergoing a nuclear reaction. The radioactive materials released would probably be persistent in the environment for a relatively long time, and they may contaminate a populated downtown area.

- A nuclear power plant accident could release similar types of radioisotopes to those released by the Chernobyl incident: both long- and short-lived radioisotopes that may cause widespread contamination. However, the scale of the disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.
- Detonation of an improvised nuclear bomb would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction that releases formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of radioactive materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time.

Switch gears – Now that we've covered a few of the basics about radioactivity and have a better feel for the types of incidents we're up against, we can get back to our story about Chernobyl. The common element to all of these types of incidents is the potential radiological contamination of a wide area. We will use the Chernobyl experience to discuss the issues involved with recovery from a wide-scale radiological event. Let's take a look at what happened at Chernobyl.

3. The Chernobyl Incident – What happened?

Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant near the town of Pripyat in what is now the Ukraine, experienced the worst nuclear power accident in history, an uncontrolled nuclear reaction and resulting explosion and fire, which sent a cloud of radioactive material over the western Soviet Union and Europe. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols, and particles and contaminating thousands of square miles in Ukraine, Belarus, Russia, and western Europe. *[image – nuclear technicians at the plant, the plant on fire, people suiting up to deal with it…]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the City of Kiev, the nearest major population center. Kiev had a population of about 2.5 million at the time of the disaster. The town of Pripyat is located about 2 miles from the reactor and had a population of about 45,000 people at the time of the accident. *[image – a map showing the three countries, the plant, Pripyat, and Kiev – we may have to make this]*

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of design flaws and operator error caused the accident. At around 1:00 AM on April 24, the plant was conducting a safety test to determine if the cooling system pumps could operate if the external power failed. The generally recognized account of the incident is that operators disabled an automatic shutdown system and powered down the reactor by inserting control rods into the core to create the low power conditions required for the test. However, the power decrease was greater than anticipated, and the operators increased the power output by manually removing some of the control rods. Within seconds of withdrawing the control rods, power in the reactor shot up to dangerous levels, creating an energy spike. Operators tried to reinsert the control rods to slow the reaction, but due to the power spike in the reactor, the rods shattered and could not be lowered further into the reactor core to control the reaction. *[Image – reactor personnel, the power plant, and a plant exploding- could be a generic explosion if we can find such a thing]*

The cooling water vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a graphite fire, and the reactor core and building burned for 10 days, releasing into the atmosphere more than 100 times the total radioactivity of the Hiroshima bombing. The fire carried radioisotopes upward into the atmosphere where they traveled with the prevailing winds. According to an IAEA report, *[IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21]* winds were initially to the northwest, but varied over the next several days so that all points of the compass were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level and deposited it, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]* ,

At the time of the accident, Ukraine was part of the former Soviet Union, a closed society with centralized control of the press. Soviet premier Mikhail Gorbachev had taken office about 1 year earlier, and had not yet implemented his policy of Glasnost, or openness. *[image of Mikhail Sergeyevich]* The first public notice of the gravity of the situation came on April 27from Sweden, when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plan on east central coast of Sweden and Chernobyl/Kiev, perhaps with an arrow showing distance between them]* Soviet authorities either did not fully understand or intentionally downplayed the severity of the accident. Evacuation of the nearby town of Pripyat began at 2:00 in the afternoon of April 27, a full 36 hours after the accident. As late as May 1, major Soviet newspapers featured May Day celebrations rather than the Chernobyl disaster on their front pages, projecting an air of normality and muting the significance of the incident. *[images of soviet newspapers – Pravda]* Soviet premier Gorbachev did not appear on television to discuss the incident until May 14, several weeks later. An initial period of silence, followed by reassuring comments from the government, appears to have had the opposite effect to that which was intended: concerned citizens feared that the incident was far worse than they were being told.

Transition: The incident involved unprecedented radiological contamination of a huge inhabited area combined with a lack of reliable information in a closed society, which created suspicion, uncertainty, and inefficiency. What can we learn from the incident? How did miscommunication and a lack of communication affect public perception and willingness to alter their lives to accommodate the new reality? How did the decontamination of the area proceed and what was life like in the affected areas?

To examine these questions, we interviewed Larisa Leonova and Vira Yakusha. Larisa is a chemist with USEPA who was one of the early responders. At the time of the accident, she was managing a laboratory in Moscow part-time while earning her PhD in chemistry. Larissa volunteered to offer her services and traveled to Kiev several weeks after the incident, and worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my Ph.D research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the incident, Vira was a resident of Kiev and a recent graduate of Kiev University. Perhaps most important, Vira was pregnant with her first child, and she brings the perspective of an expecting mother, and a member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, who's life*

was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."

4. The Early Response

We'll certainly be able to identify some good footage/photos of this part, then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes (nuclear reactions) We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine KI tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. The first on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. By 5:00 AM, the firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died of exposure to radiation within days or weeks. *[They are commemorated with a statue in the town of Pripyat – image of the famous firefighter statue?]*

To put out the fire in the core, the authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[image of helicopters dropping bags of stuff]* and injecting liquid nitrogen into the surrounding soil in order to cool the reactor. These efforts were not terribly effective at first – because of the extremely dangerous conditions and the extremely hot graphite fire, it took workers 10 days to put out the fire in the core.

Although the very first responders – the firefighters and the soldiers who first arrived on the scene to put out the fires – did not realize that the disaster was releasing high levels of radioation, the authorities soon recognized that the disaster had exposed the core and was releasing highly radioactive particles and smoke, and ordered evacuation of the surrounding area. The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the disaster. The residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[image – there are lots of images of evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The USSR Ministry of Public Health had set maximum permissible radiation limits for workers based on a one year exposure. However, the limit assumed a person would only be exposed to the radiation while working, or less than 1/3 of a year instead of the entire year. This limit was used to determine the area that would be evacuated and become known as the Chernobyl Exclusion Zone. The zone was determined to be a 30-kilometer (about 19 miles) radius around Chernobyl.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Important to demonstrate residual sources – Image – a generic trench and pile of dirt. Doesn't have to be from Chernobyl]*

After cleaning the blast area, a structure known as *the sarcophagus* was constructed of concrete, steel plates, and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[images of the sarcophagus abound. Let's get some]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safe confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience]*

5. The New Reality –*The focus of this section is what happened right afterwards in Kiev. The structure of this section will go into the nuts and bolts of living in the contaminated environment interspersed w/ tidbits from interviews. The objective is to pair "what they did" with what CDC says you are supposed to do, and to examine it in the order of: information flow, hygiene that immediately knocks back the contamination (washing, clothing), the food supply (food, farmland, etc.), and cleaning up the town.*

After the immediate issues of putting out the fires, evacuating the exclusion zone, gathering up and removing the radioactive debris, and isolating the reactor were taken care of, life continued in the surrounding areas. However, in the face of an unprecedented event, the local and national authorities were uncertain how to proceed. Larissa Leonova, a chemist who now works for USEPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."] and*
>
> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."] and*

[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."] and

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

5.1 Information Sources

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information. At the time of the accident, the Soviet Union was a closed society, and the official Soviet news sources were not known for their openness. Almost a week after the accident, the major newspapers were not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. As a result, citizens were forced to turn to informal news channels, networks of associates, and whatever international news they could find on short-wave radios.

[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially -- almost like a week after the accident happened. When I first time heard about it -- it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get -- what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that". But you know from that moment on we were basically very ah, uptight and tried to catch any news we could."] and/or

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual] and

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if -- if I would start questioning."

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]

If a similar incident were to happen in the U.S., we can expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control (CDC), the U.S. Environmental Protection Agency (U.S. EPA) and other agencies would post information on what do. Some good internet sites to obtain information on how the public should respond to a radiological incident can be found at the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov]* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation]* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

> *[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they -— that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.*
> *I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."] and*

> *[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]*

Close this section with

> *[VY4 2:41:07 - 2:2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]*

> *[Not sure this is the right place for this quote, but it touches on the transparency issue that is the heart of this section … JC1 5:06:45 - 5:07:29 "here in America, our culture is one who is much more informed of the area and will have a lot more activity uh, and involvement in the decision-making. Which can make this process cumbersome, and much longer uh, as opposed to living in a culture where you were dictated what was going to happen and how things were going to be done. That's not likely to occur here. Um, so it could be a challenge for us to deal with all the different stake holders which is an important process. The big lesson is, transparency, tell them the truth and dealing with some of the toughest questions are ultimately what going to make this a successful effort for the agency."]*

5.2 Food Supply

The massive amount of radioactive fallout had far-reaching consequences. Internal exposure to radiological contaminants through consumption of contaminated food and water is a very significant exposure mechanism and the food supply was an immediate concern. According to an IAEA review of the incident, the most effective countermeasures were prohibiting animal feeding with pasture grasses in the affected areas and rejection of milk based on radiological monitoring. 20,000 agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. Due to lack of forage and animal care facilities, an additional 120,000 animals were slaughtered from May to June 1986. *[image – here we can show images of pigs and cows being screened with radioactivity meters by a guy in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]* Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. " and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Vira Yakusha explains *her* dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
>
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:44 – 2:28:12 "And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeing our baby these apples for quite a long time while they lasted."*

Effects of the disaster were profound and long-lasting. As time went on and the threats posed by contaminated farmland became better understood, the local authorities undertook more sophisticated measures to manage agricultural production from contaminated farmland. According to Mikhail Balinov of the International Atomic Energy Agency (IAEA), the most effective countermeasures were soil treatment; removal of some areas from agricultural production altogether based on radiological screening; switching to fodder crops such as rapeseed that don't assimilate key radionuclides in the contaminated areas; switching animals to clean fodder from uncontaminated areas before slaughter and milking; and feeding animals dietary supplements such as cesium binders to help the radionuclides pass through the animals without being incorporated in food products. *[image: Here we can show images like the guys in moon suits walking through a field (42-15800571), a guy with a rototiller (42-15784775), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]. [I think the preceding paragraph is important to keep hitting the "life goes on, radioactive contamination can be managed" theme.]*

The countermeasures described above went a long way to reducing the radiological contamination of foods from the affected areas. However, economic hardship caused by dissolution of the Soviet Union reduced the effectiveness of the agricultural countermeasures. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for Cesium -137, according to R. M. Alexakhin and others of the Russian Institute of Agricultural Radiology and Agroecology. *[This seems to undermine the earlier message that things can be managed, but maybe it's important to note that it's not going to be perfect?]*

We close with an image of John saying something to the effect that we can't undo it, we have to manage it – the quote below is as close as I could find, and it fits this section reasonably well.]

> *[JC1 05:06:25- 5:06:43 "I think one of the largest lessons that I'm learning from the Chernobyl environment is that well, we have a contaminated area that we will never be able to get back to natural background levels. We can't turn the clock back, is what one of the quotes was said. I think that that's reality."]*

5.3 Hygiene Precautions

Contaminated dust and dirt are a very significant source of contamination to the public in the aftermath of a nuclear incident. CDC's radiation emergency web page [www.bt.cdc.gov/radiation] recommends leaving outer clothing and shoes outside and showering after an incident to reduce or eliminate radiological contamination. More recommendations can be found at the CDC web site. *[image – web address and screen shot. There's also a cheesy but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]* Once the local authorities accepted the significance of the Chernobyl incident, they began to issue advice on hygienic practices to reduce exposure to contaminated dust:

> *VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."*
>
> *VY3 02:25:56 - 02:26:32 " After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."*
>
> *VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you can not be 100% sure, of course. And later on, of*

course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."

Closing statement - One of the primary ways the public is exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by CDC and other sources. These websites provide good information on actions you can take to minimize your exposure after a radiological incident. *[image CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.]*

5.4 Children/pregnancy

Exposure to radiation can cause health problems for the general population, depending on the type of radiation, the exposure, and the individual's general health and susceptibility to illness. Some populations are particularly susceptible to the affects of radiation, and these include pregnant women and especially unborn babies. The Centers for Disease Control say that unborn babies are particularly sensitive to radiation during their early development, between weeks 2 and 15 of pregnancy, and can experience severe health effects such as birth defects, stunted growth, and brain damage. From 16- to 25-weeks, unborn babies may experience health consequences, but only if the doses radiation are very large, such as large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the radiation sensitivity of an unborn baby is similar to that of a newborn. *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp]*

For the people affected by Chernobyl, radiation exposure of unborn babies was a major concern. Ms. Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying the same, and Vira was unable to buy a train or plane ticket *[image –we can show a few generic Russian-looking pregnant women and happy babies, perhaps a bunch of Russians queued up at a ticket booth… We do have some photos of kids hooked up to tubes and wires, and one with their head marked in obvious prelude to brain surgery, but I think they are too negative and unsettling]*

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much*

the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."
[Image – How about a man standing next to an old, Soviet-style car?]

Vira left Kiev that night, and gave birth to Doreena, a healthy baby girl, four months later in Moscow. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "my personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

[Note – one danger of this section is that it gives some cause for panic – I feel that the 'woman in the street' perspective is valuable, but the message is get the hell out of Dodge, and it appears that Vira's actions may have saved the day. If I was a pregnant woman watching this, I'd think – get away first and ask questions later. Just want to be sure we're OK with that message.]

5.4 Decontamination of Kiev

[I'm not certain how much we want to devote to how we would do things here. I reviewed the PAGs and my brief PAG description could be beefed up. I didn't spend a lot of effort on it, as I think John will have some very detailed ideas of where he wants it to go. Note that the PAG document is very detailed, yet also very flexible. Explaining the nuances of that document is not the focus of this documentary. I think the more important message is that there is a process for getting on with life after an accident, that it's already figured out, and that we'll employ it after an accident if we need to. That's how I shaded the discussion.]

Intentional detonation of a nuclear device is likely to take place in a city, and thus is quite different from the rural environment surrounding the Chernobyl plant. One of the most significant affects of the Chernobyl accident was contamination of locally grown food, which is not likely to be a significant concern in a modern American city. Nevertheless, the Chernobyl disaster contaminated urban areas such as Kiev, and lessons about decontaminating the urban environment following Chernobyl are relevant for a radiological incident in the U.S.

In the early period after the incident, military personnel decontaminated the area. Inhalation of dust particles was a particular concern, and the area around the plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water, which suppressed the dust and rinsed the radionuclides into sewer system. *[Image – guys spraying water on trucks, buildings, and streets – we have several]*

Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, contaminated soils were removed (especially along drip lines next to buildings) *[image guys peeling back sod (42-15785116)]*, and sediments were removed from the bottom of reservoirs. Decontamination focused on schools, hospitals and other buildings with large numbers of people. Tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*

> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*

> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*

> *VY4 2:57:19 – 2:58:00 "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."*

> *VY4 2:59:54 – 3:00:00 "And of course, it's, it was very good to know that somebody is caring something is done."*

The urban decontamination experience after Chernobyl gives us an idea of what techniques were most effective to reduce exposure to contamination in Kiev. Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. According to IAEA, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but are costly and difficult to clean. *[images – Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards]*

Based on their accumulated experience, IAEA recommends:

- Removing the upper 2- to 4-inches of soil in front of residential buildings; around schools and public buildings, in private gardens; and along roadsides.
- Replacing soils that are removed by clean soils from holes dug in less trafficked areas, and filling those holes with contaminated surface soils. Although the surface soils used to fill the holes may be contaminated, they are unlikely to be contaminated enough to merit special treatment as radiological waste.
- Covering the decontaminated parts of courtyards, etc., with a layer of clean sand or gravel where soil is not available to attenuate residual radiation.

- Washing streets and buildings
- Cleaning or replacing roofs.

In the U.S., EPA has prepared a Manual of Protective Action Guidelines (PAGs) for nuclear accidents to guide responding to an incident and cleaning up and restoring contaminated areas. *[Image – the PAG document cover, and perhaps a few shots of key areas like the figure showing zones to evacuate, shelter in place, etc (Figure 7-1), a schedule of events (Figure 7-2), and perhaps some tables of particular isotopes, like Table 7-1 and 7-5. The information will not come across on screen; It's too detailed and dense, but it looks somewhat impressive and it shows that we have such a thing.]* The PAG document is a complex compendium of information that provides a flexible framework for responding to release of radiological contaminants. The document provides guidelines for establishing exclusion zones, relocating residents, and actions to reduce exposure. The document will guide emergency responders, and provides key information and some basic considerations that should be accounted for in responding to an emergency situation, and also provides guidance on the early, intermediate, and long-term responses – the actions to take to address an emergency and then bring life back to normal in the affected areas. For example, the PAGs establish techniques to estimate dose for one year based on internal exposure and external exposure to radiological contaminants, and specifies a numerical dose value for relocating the population that is exposed to levels above the numerical value. Below the value, EPA recommends dose reduction techniques, such as washing building and hard surfaces, spot soil removal, plowing to distribute and bury the surficial contamination, and spending less time outdoors. The guidance recommends focusing initial efforts on residences of pregnant women.

The PAG document also provides guidelines for when to administer dietary supplements to counteract internal exposure, how to determine when decontamination is effective, when and how to restrict food supplies, and a myriad of other considerations. In short, EPA has established a flexible framework describing how to respond to radiological emergencies, so all of the authorities involved share a common set of goals and methods to achieve them. A U.S. response to radiological emergency would not have to be improvised.

[Note: At this point, I did not feel comfortable taking the story farther without concrete guidance on where we want to go. We could go into more detail about the PAGs, but I feel that this will lose the viewers. So basically I structured this section as follows: Here's what they did in Kiev, here's what IAEA recommends, and we have a document that will tell us how to figure out these same issues here in the U.S. We have a challenge in the visuals for this part need to liven it up a bit. This piece naturally segues into the close – We're ready for something similar if it were to happen here.]

Epilogue: U.S. response to a similar incident

Recap:

- We'll have a much more transparent flow of information
- The place is never going to be cleaned up to background or pre-incident state, but it's not the end of the world
- We've got better decon technology, and we won't have to make it up as we go along
- We have a plan in place for figuring out how to proceed after a nuclear incident

Close with a reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

Some other good quotes that we could weave into the story:

VY3 02:29:45 2:29:56 "they are very dear friends of mine. Ah, a husband and wife and wife was my classmate in the University. And she is a wonderful woman. Full of life, full of energy. Smart bride."

VY3 02:30:53- 2:30:55 "And three years after Chernobyl she developed breast cancer. And ah, later on ah, information was more readily available. And later on we learned that this particular day when they were planting potatoes that cloud of radiation." ~~And it was, again it was a Russian Roulette.~~ "It was ah, radiation was blowing where the wind was blowing.

VY3 02:31:21-2:31:47 "And ah, radiation cloud was passing above us. On top of us and I was sitting in the shadow at that moment. And she was exposed to the sun working in the field, and ah, she got sick. And ah, some and she died later." So, um, and it was terrible ah, shock for me. Very personal. And every time I think about it, I wish I could rewind the, the movie and get her out from that." < good footage. Near tears

VY4 02:48:48- 2:49:18 " the worst thing about the whole ah, Chernobyl is invisible menace, menace situation, that ah, you can not definitely tell or prove that if you have some health problems is because of you were not careful enough or you were overexposed. Or just, I mean people get sick all the time. And ah, ah like I mentioned. My friend who died and ah, I, you ask me, I'm still in the heart of my heart, I'm sure that this was because what it was."

VY3 2:31 55 -2:32:40 "Do you perceive yourself as a survivor? No. I think I'm, I'm um, more or less of a bystander. Because I am um, more or less a bystander. Because I, I have seen again you've seen this information. And there were people who were sacrificing their lives to contain this horrible accident. Who were doing most, more than everybody could ask from the others. Um, um, doing more than everybody could ask from the other human being. And um, I was just trying to make sure that my baby and I am healthy. And ah, it worked well, very well for me so I, I just um, I, I, pray for people who are much more affected than I am. I don't feel sorry for myself."

Windowsill showed contamination: VY4 02:51:19 – 2:51:44 "Well, what we did, of course we washed it. Well, what we did, we washed it a little bit. With soap and sponge. And of course we disposed of the sponge and throw away. And then we ah, ah, we covered it over with a layer of fresh paint. So it's ah, sort of to seal in the particles that were still radioactive to prevent them from dislodging and getting into your fingers, for example."

VY4 2:56: 51 – 2:58:03 "did you feel that the government needed to continue to clean up to levels before the tragedy or did they just accept living in a contaminated environment? Ah, ah, I guess everybody, I guess everybody understood that it was not visible. Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that. So something that was contaminated could be ah, took out from the ah, ah, recycling. Life cycle so to speak. For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the, in the, in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."

VY4 02:46:05– 2:47:42 "our whole culture is very much, uh, agriculture or centered ah, centered around agricultural cycles. And ah, it's very much in our ah, everyday culture for people who have perfectly good paying ah professional jobs still to maintain some garden plots outside or inside the city *and trying to grow their own vegetables or their own apples. Ah, and it was only in part economical necessity and a big part of it is just desire to have something that you watch growing. And people kept doing this. But again there was a, a whole spectrum of responses from some of our people who just quit doing this altogether or just keep planting but they would not consume what they grew. And many people continued to grow and eat what they grew. And some of them would follow uh, those um, guidelines. Turn the soil over. Put probably what I've heard put more calcium in the soil so it will ah, ah, sort of neutralize some bad elements. And uh, I've seen people who just didn't care much and they were thinking oh you cannot touch it, you cannot smell it, it's clean. Why do I bother? So ah, there's a, the whole, again, the whole rainbow of responses from probably super-paranoid and like I was trying not to eat bread for two weeks and see how it go to more than relaxed. And probably truth is always somewhere in between."*